Protection of technical installations intended for use in Ex areas against explosions

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Abstract. This paper analyzes the fundamental methods and principles for protecting technical installations used in explosive atmospheres (Ex zones), in order to prevent catastrophic events. The study covers relevant European regulations (ATEX Directive), classification of hazardous areas, and the design and technological solutions that enable safe operation of equipment in such environments. The paper focuses both on theoretical aspects and the practical applicability of explosion protection measures, aiming to increase industrial safety levels.

1 Introduction

In most modern industrial branches, there are technological processes that involve the use, handling or generation of flammable substances.

Under certain conditions, they can form explosive atmospheres with air, creating a significant risk to the safety of personnel and equipment. Areas where these conditions are possible are defined as Ex areas.

In order to prevent the occurrence and consequences of explosions, it is essential to implement explosion protection measures.

These measures are regulated by both European directives and international standards.

An assessment of the importance of all potential ignition sources that are likely to come into contact with the explosive atmosphere is required. is required.

The ignition source related to the equipment represents any possible source of ignition that is produced by the equipment considered, regardless of its ignition capacity.

2 Theoretical background

2.1 Definition of explosive atmosphere and Ex zones

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An explosive atmosphere is a mixture of flammable substances with air, which can cause an explosion.

Ex zones are classified as follows:

For vaporous gases or mists:

- Zone 0: permanently present explosive atmosphere
- Zone 1: probable atmosphere under normal conditions
- Zone 2: unlikely and short-term atmosphere

For dust:

- Zone 20: explosive dust-air mixtures are present permanently or frequently
- Zone 21: explosive dust-air mixtures are likely to occur
- Zone 22: explosive dust-air mixtures are not likely to occur during normal operation

2.2 Ignition source

An explosion is only possible if an ignition source is present and if the concentration of the flammable substance falls within the explosive range. Recent research has shown that local electrostatic discharges, with intensities much higher than the measured average, can constitute hidden ignition sources in powder handling processes [1].

2.3 European regulations: ATEX Directive

The ATEX Directive 2014/34/EU regulates equipment and protective systems in explosive atmospheres. Classification: Group I – mining, Group II – general industry; categories 1, 2, 3 depending on the level of protection.[2]

Relation between Equipment protection levels (EPLs) and zones

SR EN ISO 80079-36		Directive 2014/34/UE (GD no. 245/2016)		SR EN 60079-10-1 SR EN 60079-10-2
EPL	Group	Equipment Group	Equipment Category	Zones
Ma	I	I	M1	Not Applicable
Mb			M2	
Ga	II	II	1G	0
Gb			2G	1
Gc			3G	2

Category 3G are intended for use in zones 2, where the risk of an explosive atmosphere is reduced. In such areas, the occurrence of flammable gases or vapors is rare and usually of short duration. For this reason, these equipments offer a level of protection considered normal, being designed to operate without generating sources of ignition in normal operating conditions.

Category 2G, the use is specific to zones 1, spaces in which the presence of an explosive atmosphere may occasionally occur. Here, the level of protection must be high, as the equipment must be safe both in normal operation and in the event of foreseeable failures.Category

Category 1G, this refers to the most severe working conditions, found in zones 0. The explosive atmosphere may be present permanently or for long periods of time, and the equipment must guarantee a very high degree of protection. Their design takes into account not only normal operation and foreseeable faults, but also possible rare faults, difficult to anticipate, in order to eliminate the risk of an ignition source.[3]

3 Methodology

The paper uses a theoretical-applicative approach, based on the analysis of relevant technical standards (ATEX, EN 60079), case studies and examples of good practices in the field of protection of installations in Ex areas.[4]

At the same time, recent recommendations regarding the selection of electrical equipment suitable for Ex areas are taken into account, highlighting the importance of correlating zone classification with the characteristics of the equipment.[5]

As an applied example, the implementation of explosion protection measures in a grain silo, a high-risk environment due to the accumulation of combustible dust, is analyzed.

4 Analysis – case study: explosion protection in a grain silo

4.1 Silo-specific Risks

Silos used for storing grain frequently generate clouds of combustible dust, especially during loading and unloading operations.

The combination of dust, air and an ignition source can lead to an explosion. Hazardous areas include hoppers, elevators and dust filters.

Grain silos are essential industrial installations in the agri-food sector, used for the controlled storage of large quantities of agricultural products.

However, from an occupational safety and plant protection perspective, these structures present a number of significant technical risks.

Among these, the risks associated with explosive atmospheres generated by grain dust, mechanical, biological and self-ignition risks stand out in particular.

4.1.1 Explosion risk generated by combustible dusts

Grains, especially during handling (transport, loading, unloading), generate large quantities of fine dust, capable of forming explosive atmospheres in combination with air.

The dust in question is recognized as a combustible substance according to Directive 2014/34/EU (ATEX) and is characterized by a major risk of deflagration in the event of the occurrence of combustion initiation factors.

According to the SR EN 60079-10-2 standard, the spaces inside the silo and in the vicinity of the transport or ventilation equipment must be appropriately classified in Ex zones (e.g. Zone 20 for the inside of the cells, Zone 21 for loading/unloading areas).[4]

Typical sources of ignition in such installations include:

- electrostatic discharges (due to friction of grains between themselves and metal surfaces);
- mechanical sparks resulting from collisions or wear of equipment;
- overheating of bearings or drive systems;
- electrical equipment unsuitable for potentially explosive environments.

4.1.2 Risk of spontaneous combustion and fermentation

Another specific risk is the spontaneous combustion of the grain mass if stored in inappropriate conditions (excessive humidity, lack of ventilation, excessive compaction).

Biological fermentation processes can generate internal heat, which leads to an increase in the temperature in the grain mass and, in extreme cases, to spontaneous combustion.

Preventing this phenomenon requires permanent monitoring of the temperature and humidity of the grain, as well as periodic aeration of the stored masses.

4.1.3 Mechanical and Burial Risks

Modern silos use mechanized equipment for grain handling, such as belt conveyors, augers, bucket elevators, etc.

These present significant risks of:

- accidents due to entrapment in moving components;
- falls from heights during maintenance work;
- accidental burial in the grain mass (especially during interventions in hoppers).

It is essential to apply workplace safety principles, including the use of personal protective equipment, lockout/tagout (LOTO) procedures, and the presence of emergency stop systems.

4.1.4 Health risks – inhalable dust and biological agents

Inhalation of fine grain dust particles is associated with chronic respiratory diseases, such as occupational asthma and allergic bronchitis.

Contaminated grains may also contain mycotoxins and fungal spores (Aspergillus, Fusarium), which affect the health of workers.

To reduce these risks, it is recommended:

- implementation of industrial ventilation systems;
- use of protective masks with an appropriate filter (e.g. P3);
- limiting the time spent in areas with high dust concentrations.

4.1.5 Electrical risks

Electrical equipment used in silos must comply with the protection requirements imposed by the Ex-zone in which they are installed.

Failure to comply with these requirements can generate electrical arcs or sparks that can trigger explosions.

The use of equipment with Ex marking (e.g. Ex t or Ex e) is mandatory, according to GD 1058/2006 on the regime of products used in potentially explosive atmospheres.[6]

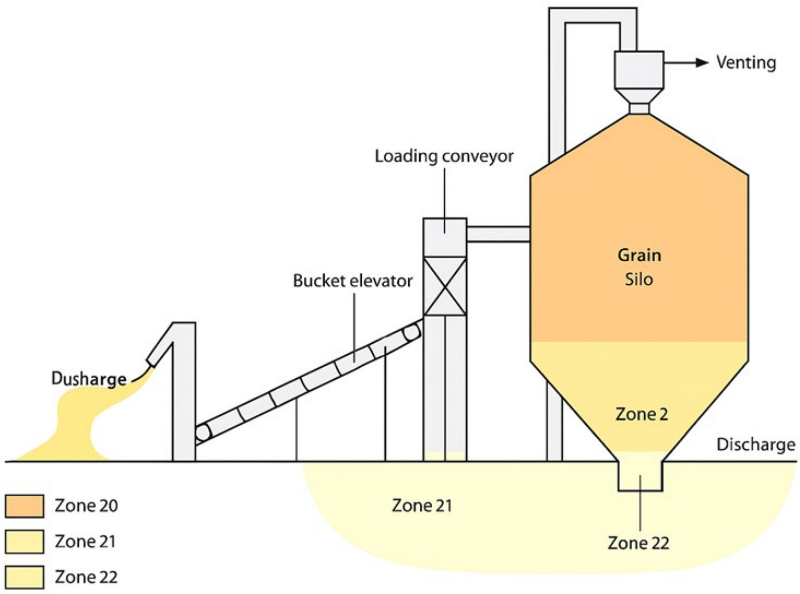
4.1.6 Environmental risks

Silos can also pose a danger to the environment, especially in the case of leakage of grains treated with pesticides or insecticides.

Also, a fire or explosion in a silo can generate toxic emissions and the dispersion of large quantities of dust and smoke into the atmosphere, affecting the soil and water in the vicinity.

4.2 Classification of Ex zones in a silo

Installations intended for the handling or storage of flammable materials must be designed, operated and maintained so that releases of substances and, implicitly, the expansion of risk areas are minimized in frequency, duration and volume, regardless of the operating mode.



According to the regulations, the areas are classified as follows:
- Zone 20: inside the silo.
- Zone 21: around the unloading points.
- Zone 22: peripheral areas, rarely exposed to combustible dust.

Once the hazardous areas have been classified, a risk assessment can be carried out to determine whether the effects of ignition of an explosive atmosphere require a higher equipment protection level (EPL) or, conversely, technical equipment with a lower level of protection than would normally be required can be used.

4.3 Technical measures applied

To avoid the creation of an explosive atmosphere caused by dispersed dust, equipment and components of protective systems must be designed in such a way that deposits of combustible material are prevented.
It is recommended to carefully monitor the following elements:

– The design of dust transport and removal systems must be based on the principles of fluid flow dynamics, in particular with regard to the routing of pipes, flow velocity, surface roughness.
– Surfaces such as structural elements, T-beams, cable ducts, sills and so-called dead spaces in equipment, protective systems and components in which dust is circulated must be reduced to a minimum.
– This can be achieved in part, for example, by choosing structural elements that offer small deposition surfaces as a result of covering or sloping surfaces, where such dust deposition is unavoidable.
– By creating smooth surfaces (e.g. floor tiles, oil paint coatings), dust adhesion can be prevented at least partially and cleaning can be facilitated.
– The use of contrasting colors makes dust deposits more visible.

- Appropriate measures must be taken for cleaning (e.g. smooth surfaces, good accessibility for cleaning, installation of central vacuum cleaning systems, power supply for mobile vacuum cleaners).
- The user instructions must emphasize that dust must be removed from heated surfaces, e.g. pipes, radiators, electrical equipment.
- Selection of appropriate emptying devices for dryers, granulators, silos and dust collection units.
- Cleaning equipment must be suitable for use with combustible dusts (e.g. no effective ignition sources).
- Ex equipment: Ex tb motors, certified sensors.
- Detection systems: spark detectors, temperature monitoring.
- Ventilation: anti-explosion filters, dust extractors
- Organizational measures: personnel training, periodic inspections.

The electrical equipment used must comply with ATEX requirements, and their selection should be made according to the Ex zone and the potential ignition sources. Recent studies emphasize that selection and installation errors represent a critical factor in industrial incidents [5]. In addition, advanced spark detection and monitoring of electrostatic discharges allow the reduction of ignition risk [1]

5 Conclusions

Given the potential of an explosion to cause major damage and endanger life, risk analysis and implementation of appropriate solutions, in accordance with applicable standards, is a crucial element for the safety of people and property.

A determining factor in the analysis of explosion risk in workplaces exposed to potentially explosive atmospheres is the equipment and installations operating in such environments.

These installations need to be designed, manufactured, installed and maintained in such a way that they are not capable of generating sources of initiation.

Therefore, measures must be taken to prevent the occurrence of ignition sources that they could generate.

Preventing explosions in Ex areas is essential for industrial safety.

In the case of silos, the risks related to combustible dusts require rigorous technical and organizational measures.

Certified equipment, detection systems and appropriate training contribute to reducing the risk of explosion.

Effective risk management in a grain silo requires an integrated approach, which combines the identification and classification of hazardous areas, the selection of appropriate equipment, continuous training of personnel, as well as the implementation of strict operating and maintenance procedures.

Compliance with national and European regulations on Ex areas (ATEX) is fundamental to prevent accidents and protect human life and the environment.

This research was carried out within the framework of the "Nucleu" Programme, part of the National Research, Development and Innovation Plan 2022–2027, and was financially supported by the Romanian Ministry of Research, Innovation and Digitalization (MCID), under project number PN23320102. The results were obtained using the Installation of National Interest – IOSIN-PCDIEx at INCD INSEMEX Petroșani, supported through public funding allocated by the Ministry of Education and Research – National Research Authority.

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